Deployment of an Indigenously Designed and Developed Mini-Orange Magnetic Spectrometer for Nuclear Structure Studies

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Introduction

Conversion electron spectroscopy and the measurements of E0 transitions are valuable tools for nuclear structure. The open question in nuclear structure regarding the existence and onset of collectivity for the low lying $K = 0^+$ excitations continues in spite of abundance reaction rates and lifetime measurements. The development of techniques for conversion electron spectroscopy in singles have excelled with high precision conversion electron measurements such as the BILL spectrometer [1]. An alternative method eventually emerged which was to arrange electro magnets like pieces of an orange to create a magnet filter. The magnet filters in this "orange spectrometer" setup created a toroidal magnetic field to direct the electrons. These designs allowed the source and the detector to be placed outside of the magnetic field and showed an improvement in detection efficiency and resolution over the solenoidal designs. The mini-orange spectrometer was pioneered by van Klinken [2] as a successor to the orange spectrometer. Kevin Lee et al [3] writes in their paper as "In recent years, new mini-orange spectrometers have continued to be developed and used in experiments, including SPICE [4] at TRIUMF in Canada, the spectrometer at Sri Sathya Sai Institute of Higher Learning [5] in India, and SLICES [6] at the Legnaro National Laboratory in Italy".

Design and development

The versatility of the spectrometer is due to the interplay of the parameters like the shape of the magnets, number of magnets, number of magnet gaps, magnetization, central absorber, detector, distances of the detector and the source from the magnets, etc. Therefore, each individual parameter was studied separately before a complete system was constructed.

1. Shape of the magnets: Filters using wedge-shaped magnets have the desirable property of focusing electrons. The wedge shape of the magnets is also required in order to obtain a nearly toroidal field, with constant field strength inside the gaps.
2. Type of magnets: $BaO.6Fe_2O_3$ magnets were chosen, considering factors such as magnetization, electron energy range, cost and ease of handling.
3. Magnet Configuration: The base of the monolithic magnet is glued to a brass holder, which slides in a ring, so that the angles φi can be adjusted at will. The ring itself can slide along the system axis, resulting in adjustable source to magnet and magnet to detector distances, f and g respectively. A configuration that gave near ideal transmission characteristics for both low and high-energy electrons was chosen.
4. Number of magnets: The nine magnet and nine gap configuration was chosen for the present study. All configurations studied have rotational symmetry with equally spaced gaps. As shown in the Fig. 1, if β and φ are the magnet and gap angles in the plane Z, the ratio $b = \beta/\varphi$ represents the blocking factor.
5. One end of the chamber has a connecting flange that mates with the front- flange of the Si(Li) detector by means of a soft-Copper 'O' ring, in a vacuum-tight environment. The other end is fitted with two vacuum seals. One of them is a Neoprene 'O' seal of about 182 mm

diameter. The other is the Wilson 'O' seal that allows a shaft to go through it into the vacuum chamber, without breaking the high vacuum. This moving shaft has a length of about 260 mm and has a 'source holder' that holds the radioactive source at the end that is inside the chamber.

6. The chamber holds the magnet assembly and the source and also allows variations in the source- magnet positions, without breaking the high vacuum. The source-magnet distance f, can be varied up to a maximum of 200 mm. The magnet-detector distance g, can be varied from a minimum of about 40 mm to almost 175 mm. Precision machining of the auxiliary support structure, that guides the screw-shaft in a straight line, ensures negligible non-linearity in the motion of the main shaft through the Wilson 'O' seal.

7. The vacuum chamber-detector assembly is connected by means of a valve on the detector assembly and neoprene tubing to the dummy chamber of the ALCATEL TURBOPACK vacuum pump. with a maximum range of $5*10^{-8}$ mbar. The complete set up of the electron spectroscopy system consisting of the miniorange electron spectrometer and the LN_2 cooled Si(Li) detector developed and optimized in our laboratory is presented in Fig. 2.

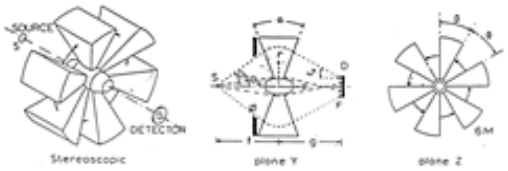

Fig. 1: Schematic view of our Mini-orange spectrometer.

Deployment for Nuclear structure studies

During the last few years our electron spectroscopy system coupled with our high resolution and high efficiency gamma spectroscopy system have brought out very interesting results in the decay spectroscopic studies in many nuclei, like: ^{71}As, ^{99}Tc,^{111}In, ^{122}Te, ^{125}Te, ^{131}Cs, ^{133}Cs, ^{160}Yb, ^{169}Tb, ^{175}Lu, ^{177}Hf, ^{177m}Lu, ^{197}Hg etc. In these studies many levels have been identified for the first time in decay spectroscopy, assigned multipolarities of many gamma transitions and spins and parities

Fig. 2: The mating of the Si(Li) detector with Vacuum chamber

of many exited states, precise mixing ratios and transition probabilities were reported. As a convincing sample of our precision measurements, we present some of our experimental ICC measurements on some pure E2 transitions in comparison with the very reliable theoretical BRICC values in Table 1.

Table 1.: Precision ICC measurements

Nucl-ide	E_γ (keV)	Multi polar ity	Internal Conversion Coefficients (ICCs)	
			Experimental	BRICC
^{111}Cd	245.48	E2	α_K = 0.054(2)	0.0535
^{153}Eu	96.88.	E2	α_K = 1.29(20)	1.28
	166.55	E2	α_K = 0.275(38)	0.273
		E2	α_M = 5.8(5)	5.76
^{177}Lu	115.87	E3	α_K = 2.00(10)	2..08
		E3	α_L = 20.5(7)	20.9
^{192}Pt	316.44	E2	α_K =0.0537(4)	0.0536
		E2	α_L =0.0232(1)	0.0233
	468.48	E2	α_K = 0.021(1)	0.0211
	884.73	E2	α_K =0.0052(2)	0.0054

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